SpringerBriefs in Applied Sciences and Technology

For further volumes:
http://www.springer.com/series/8884

Koji Sugioka · Ya Cheng

Femtosecond Laser 3D Micromachining for Microfluidic and Optofluidic Applications

Springer

Koji Sugioka
Laser Technology Laboratory
RIKEN
Saitama
Japan

Ya Cheng
State Key Laboratory of High Field Laser Physics
Shanghai Institute of Optics and Fine Mechanics
Chinese Academy of Sciences
Shanghai
People's Republic of China

ISSN 2191-530X ISSN 2191-5318 (electronic)
ISBN 978-1-4471-5540-9 ISBN 978-1-4471-5541-6 (eBook)
DOI 10.1007/978-1-4471-5541-6
Springer London Heidelberg New York Dordrecht

Library of Congress Control Number: 2013948353

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Femtosecond lasers are becoming very common tools for laser materials processing, both for fundamental investigations and various applications including practical uses. Despite this, materials processing using femtosecond lasers does not have a very long history. It was initiated in 1987 when Srinivasan and co-workers and Küper and co-workers demonstrated clean ablation of polymethyl methacrylate (PMMA) with little formation of a heat-affected zone. Furthermore, Küper and co-workers showed that due to their extremely high peak intensities, femtosecond lasers can perform clean ablation of even transparent materials such as NaCl and polytetrafluoroethylene (PTFE) via multiphoton absorption. These experiments had a great impact on many researchers so that research in this field increased rapidly in the 1990s. In 1996, Hirao and co-workers and Mazur and co-workers demonstrated that the interiors of transparent materials such as glasses can be modified or machined by a tightly focused femtosecond laser beam with a moderate pulse energy. This ability was widely used to fabricate three-dimensional (3D) photonic devices such as optical waveguides, optical couplers and splitters, volume Bragg gratings, Fresnel zone plates in glass chips. In 2001, Misawa and co-workers fabricated 3D microfluidic channels in glass by internal modification using a femtosecond laser followed by wet chemical etching. Since 2003, we have been using this ability of femtosecond lasers to perform 3D micromachining inside glass to fabricate biomicrochips such as microfluidics, microreactors, lab-on-a-chip devices, micro-total analysis systems (μ-TAS), and optofluidic devices. Biomicrochips have revolutionized many fields including biochemical analysis since they can be used to perform biochemical analysis with a high efficiency and accuracy and can reduce reagent consumption, waste production, analysis time, and labor costs. We have demonstrated that femtosecond laser processing has many advantages for biomicrochip fabrication over conventional fabrication techniques such as traditional semiconductor processing and soft lithography since it directly fabricates true 3D microfluidic structures and integrates some functional microcomponents including micro-optical, micromechanic, and microelectronic components. Consequently, biomicrochip fabrication is becoming one of the most important and promising applications of femtosecond laser processing and many researchers are working in this field.

Despite the rapid growth in femtosecond laser processing, only a few books have been published on it to date. These books review the fundamental aspects or discuss the wide range of applications of femtosecond laser processing. We considered that a book that focuses specifically on biomicrochips fabricated by femtosecond lasers would be beneficial for researchers working in this and related fields. This book describes biomicrochip fabrication by 3D fabrication techniques inside glass based on femtosecond lasers. It contains many illustrations and photographs cited from papers published by ourselves and other groups. It comprises 10 chapters, namely the introduction (Chap. 1), current techniques for fabricating microfluidic and optofluidic components (Chap. 2), fundamentals of femtosecond laser processing (Chap. 3), fabrication of microfluidic structures (Chap. 4), fabrication of fluid control microdevices (Chap. 5), fabrication of micro-optical components (Chap. 6), selective metallization (Chap. 7), integration of functional microcomponents Chap. 8), applications of biomicrochips for biological analysis (Chap. 9), and a summary and outlook for this field (Chap. 10). This book thus provides a comprehensive review of the state of the art and future prospects as well as fundamental aspects of this field. We hope that this book will be beneficial for students and young scientists who either are considering working or have just started working in femtosecond laser processing or biomicrochips as well as for researchers and engineers in both academia and industry who are already working in these fields.

Finally yet importantly, we would like to thank Shoji Maruo, Andreas Ostendorf, Malcolm Gower, Yoshiki Nakata, Shigeki Matsuo, Roberto Osellame, Costas Grigoropoulos, and Yves Bellouard for allowing us to use their original figures in this book. We would also like to thank Lingling Qiao for her technical assistance in editing this book.

December 2012

Koji Sugioka
Ya Cheng

Contents